

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
REQUEST FOR FILING NATIONAL PHASE OF
PCT APPLICATION UNDER 35 U.S.C. 371 AND 37 CFR 1.494 OR 1.495

09/830778

To: Hon. Commissioner of Patents
 Washington, D.C. 20231



00909

TRANSMITTAL LETTER TO THE UNITED STATES
 DESIGNATED/ELECTED OFFICE (DO/EO/US)

Atty Dkt: P 280281 /2409719/2252353
 M# /Client Ref.

From: Pillsbury Winthrop LLP, IP Group:

Date: May 1, 2001

This is a **REQUEST** for **FILING** a PCT/USA National Phase Application based on:

- | | | | | | | | | | | | | | | |
|--|--|------|---------|------|-----|-------|------|---|---|----------|------|-----|-------|------|
| 1. International Application

<u>PCT/AU99/00940</u>
<u>1</u> country code | 2. International Filing Date

<table border="0"> <tr> <td>29</td> <td>October</td> <td>1999</td> </tr> <tr> <td>Day</td> <td>MONTH</td> <td>Year</td> </tr> </table> | 29 | October | 1999 | Day | MONTH | Year | 3. Earliest Priority Date Claimed

<table border="0"> <tr> <td>4</td> <td>November</td> <td>1998</td> </tr> <tr> <td>Day</td> <td>MONTH</td> <td>Year</td> </tr> </table> (use item 2 if no earlier priority) | 4 | November | 1998 | Day | MONTH | Year |
| 29 | October | 1999 | | | | | | | | | | | | |
| Day | MONTH | Year | | | | | | | | | | | | |
| 4 | November | 1998 | | | | | | | | | | | | |
| Day | MONTH | Year | | | | | | | | | | | | |
4. Measured from the earliest priority date in item 3, this PCT/USA National Phase Application Request is being filed within:

(a) ☐ 20 months from above item 3 date (b) ☒ 30 months from above item 3 date,

(c) Therefore, the due date (unextendable) is May 4, 2001

5. Title of Invention NON-PRIMARY DETONATORS

6. Inventor(s) COOPER, John et al

Applicant herewith submits the following under 35 U.S.C. 371 to effect filing:

☒ Please immediately start national examination procedures (35 U.S.C. 371 (f)).

☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2)) is transmitted herewith (file if in English but, if in foreign language, file only if not transmitted to PTO by the International Bureau) including:

a. ☒ Request;

b. ☒ Abstract;

c. 51 pgs. Spec. and Claims;

d. 3 sheet(s) Drawing which are ☐ informal ☒ formal of size ☒ A4 ☐ 11"

9. ☒ A copy of the International Application has been transmitted by the international Bureau.

10. A translation of the International Application into English (35 U.S.C. 371(c)(2))

a. ☐ is transmitted herewith including: (1) ☐ Request; (2) ☐ Abstract;

(3) _____ pgs. Spec. and Claims;

(4) _____ sheet(s) Drawing which are:

☐ informal ☐ formal of size ☐ A4 ☐ 11"

b. ☐ is not required, as the application was filed in English.

c. ☐ is not herewith, but will be filed when required by the forthcoming PTO Missing Requirements Notice per Rule 494(c) if box 4(a) is X'd or Rule 495(c) if box 4(b) is X'd.

d. ☐ Translation verification attached (not required now).

11. ☒ Please see the attached Preliminary Amendment
12. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)), i.e., before 18th month from first priority date above in item 3, are transmitted herewith (file only if in English) including:
13. ☒ PCT Article 19 claim amendments (if any) have been transmitted by the International Bureau
14. ☐ Translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)), i.e., of claim amendments made before 18th month, is attached (required by 20th month from the date in item 3 if box 4(a) above is X'd, or 30th month if box 4(b) is X'd, or else amendments will be considered canceled).

15. **A declaration of the inventor** (35 U.S.C. 371(c)(4))

- a. ☐ is submitted herewith ☐ Original ☐ Facsimile/Copy
- b. ☒ is not herewith, but will be filed when required by the forthcoming PTO Missing Requirements Notice per Rule 494(c) if box 4(a) is X'd or Rule 495(c) if box 4(b) is X'd.

16. **An International Search Report (ISR):**

- a. Was prepared by ☐ European Patent Office ☐ Japanese Patent Office ☒ Other
- b. ☒ has been transmitted by the international Bureau to PTO.
- c. ☒ copy herewith (1 pg(s.)) ☒ plus Annex of family members (1 pg(s.)).

17. **International Preliminary Examination Report (IPER):**

- a. ☒ has been transmitted (if this letter is filed after 28 months from date in item 3) in English by the International Bureau with Annexes (if any) in original language.
- b. ☒ copy herewith in English.
- c.1 ☒ IPER Annex(es) in original language ("Annexes" are amendments made to claims/spec/drawings during Examination) including attached amended:
- c.2 ☒ Specification/claim pages #1,1A,5,6,11,13,17,18,18A,31 - 36 claims # 1 - 34
Dwg Sheets #
- d. ☐ Translation of Annex(es) to IPER (required by 30th month due date, or else annexed amendments will be considered canceled).

18. **Information Disclosure Statement** including:

- a. ☒ Attached Form PTO-1449 listing documents
- b. ☐ Attached copies of documents listed on Form PTO-1449
- c. ☒ A concise explanation of relevance of ISR references is given in the ISR.

19. ☐ **Assignment** document and Cover Sheet for recording are attached. Please mail the recorded assignment document back to the person whose signature, name and address appear at the end of this letter.

20. ☐ Copy of Power to IA agent.

21. ☐ **Drawings** (complete only if 8d or 10a(4) not completed): ___ sheet(s) per set: ☐ 1 set informal;
☐ Formal of size ☐ A4 ☐ 11"

22. Small Entity Status ☒ is **Not** claimed ☐ is claimed (pre-filing confirmation required)

22(a) ___ (No.) Small Entity Statement(s) enclosed (since 9/8/00 Small Entity Statements(s) not essential to make claim)

23. **Priority** is hereby claimed under 35 U.S.C. 119/365 based on the priority claim and the certified copy, both filed in the International Application during the international stage based on the filing in (country) CANADA & AUSTRALIA of:

Application No.		Filing Date	Application No.		Filing Date
(1)	2,252,353	Nov. 4, 1998	(2)	PQ 2315	August 19, 1999
(3)	_____	_____	(4)	_____	_____
(5)	_____	_____	(6)	_____	_____

- a. ☒ See Form PCT/IB/304 sent to US/DO with copy of priority documents. If copy has not been received, please proceed promptly to obtain same from the IB.
- b. ☐ Copy of Form PCT/IB/304 attached.

RE: USA National Phase Filing of PCT/AU99/00940

JG18 Rec'd PCT/PTO 01 MAY 2001

24. Attached: Copy of Form PCT/IB/306

25. Per Item 17.c2, **cancel original** pages #____, claims #____, Drawing Sheets #**26. Calculation of the U.S. National Fee (35 U.S.C. 371 (c)(1)) and other fees is as follows:**Based on amended claim(s) per above item(s) ☐ 12, ☐ 14, ☒ 17, ☐ 25 (hilitte)

Total Effective Claims	minus 20 =	x \$18/\$9	= \$0	966/967
Independent Claims	minus 3 =	x \$80/\$40	= \$0	964/965
If any proper (ignore improper) Multiple Dependent claim is present,		add\$270/\$135	+0	968/969

BASIC NATIONAL FEE (37 CFR 1.492(a)(1)-(4)): →→ **BASIC FEE REQUIRED, NOW** →→→→A. If country code letters in item 1 are not "US", "BR", "BB", "TT", "MX", "IL", "NZ", "IN" or "ZA"

See item 16 re:

- | | | |
|--|----------------------|---------|
| 1. Search Report was <u>not</u> prepared by EPO or JPO ----- | add\$1000/\$500 | 960/961 |
| 2. Search Report was prepared by EPO or JPO ----- | add\$860/\$430 +1000 | 970/971 |

SKIP B, C, D AND E UNLESS country code letters in item 1 are "US", "BR", "BB", "TT", "MX", "IL", "NZ", "IN" or "ZA"

- ☐ B. If USPTO did not issue both International Search Report (ISR) and (if box 4(b) above is X'd) the International Examination Report (IPER), ----- add\$1000/\$500 +0 960/961
- ☐ C. If USPTO issued ISR but not IPER (or box 4(a) above is X'd), ----- add\$710/\$355 +0 958/959
- ☐ D. If USPTO issued IPER but IPER Sec. V boxes not all 3 YES, ----- add\$690/\$345 +0 956/957
- ☐ E. If international preliminary examination fee was paid to USPTO and Rules 492(a)(4) and 496(b) satisfied (IPER Sec. V all 3 boxes YES for all claims), ----- add \$100/\$50 +0 962/963

27. **SUBTOTAL =** \$1000

28. If Assignment box 19 above is X'd, add Assignment Recording fee of ---\$40 +0 (581)

29. Attached is a check to cover the ----- **TOTAL FEES** \$1000

Our Deposit Account No. 03-3975

Our Order No. 21058 | 280281

C#

M#



00909

CHARGE STATEMENT: The Commissioner is hereby authorized to charge any fee specifically authorized hereafter, or any missing or insufficient fee(s) filed, or asserted to be filed, or which should have been filed herewith or concerning any paper filed hereafter, and which may be required under Rules 16-18 and 492 (missing or insufficient fee only) now or hereafter relative to this application and the resulting Official document under Rule 20, or credit any overpayment, to our Account/Order Nos. shown above for which purpose a duplicate copy of this sheet is attached.

This CHARGE STATEMENT does not authorize charge of the issue fee until/unless an issue fee transmittal form is filed

Pillsbury Winthrop LLP
Intellectual Property Group

By Atty: Paul N. KokulisReg. No. 16773

Sig:

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NOTE: File in duplicate with 2 postcard receipts (PAT-103) & attachments.

09/830778

JC18 Rec'd PCT/PTO 01 MAY 2001

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re PATENT APPLICATION OF

Inventor(s): COOPER, John et al

Filed: Herewith

Title: NON-PRIMARY DETONATORS

May 1, 2001

PRELIMINARY AMENDMENTHon. Commissioner of Patents
Washington, D.C. 20231

Sir:

Please amend this application as follows:

IN THE SPECIFICATION:

At the top of the first page, just under the title, insert

☒ --This application is the National Phase of International Application
PCT/AU99/00940 filed October 29, 1999 which designated the U.S.
and that International Application

☒ was ☐ was not published under PCT Article 21(2) in English.--

Respectfully submitted,

PILLSBURY WINTHROP LLP
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09/830778

- 1 -
PTO/PCT Rec'd 1 MAY 2001Non-primary DetonatorsField of the Invention

5 The present invention relates to explosive detonators comprising compositions which are characterized by being essentially free from molecular primary explosives, to compositions suitable for use in detonators, and to the manufacture of detonators.. The invention further relates to initiating elements for use in detonators and to a method of blasting.

10

Description of the Related Art

Detonators, including electronic, electric and non-electric types, are widely employed in mining, quarrying and other blasting operations. In-hole detonators
15 are generally used to initiate an explosive charge which has been placed in a borehole, while surface detonators are generally used outside of the borehole to initiate one or more explosive initiating signal means such as shock tube or detonating cord.

Modern commercial detonators typically comprise, in the case of an in-hole
20 detonator, a metallic shell which is closed at one end and which contains, in sequence from the closed end, a base charge of a detonating, secondary explosive, such as for example, pentaerythritoltetranitrate (PETN), and a primer charge of a heat-sensitive, detonable, primary explosive, such as for example, lead azide, which is above and adjacent to the base charge. In a delay detonator,

AMENDED SHEET
IPE/AU

- 1A -

adjacent the primary explosive is an amount of a deflagrating or burning
composition of sufficient quantity to provide a desired delay time. Above the delay
composition (if present) is an electric match, a low energy detonating cord or
shock wave conductor (such as shock tube), or the like, retained in the open end
5 of the metallic shock.

Surface detonators are generally identical to in-hole detonators with the
exception that the base charge of high explosive is preferably reduced or omitted
to give lower output. The output is preferably reduced to a level sufficient to
initiate adjacent shock tube, detonating cord and the like, without, for example,

throwing excessive amounts of shrapnel which can damage nearby lengths of shock tube or cord. This feature of output control is a desirable practise in the design of detonators in order to control the energy output of in-hole and surface detonators.

5 For the purposes of this specification, a primary explosive is defined as an explosive substance which readily develops complete detonation from stimuli such as flame, conductive heating, impact, friction or static electrical discharge, even in the absence of any confinement. In contrast, a secondary explosive can generally only be detonated if it is present in larger quantities or if contained
10 within heavy confinement such as a heavy walled metal container, or by being exposed to significant shock wave or mechanical impact. Examples of primary explosives are mercury fulminate, lead styphnate, lead azide and diazodinitrophenol (DDNP) or mixtures of two or more of these and/or similar substances. Representative examples of secondary explosives are (PETN),
15 cyclotrimethylenetrinitramine (RDX), cyclotetramethylenetetranitramine (HMX), trinitrophenylmethylnitramine (Tetryl) and trinitrotoluene (TNT) or mixtures of two or more of these and/or other similar substances.

The use of lead azide as a heat-sensitive, primary explosive material, or as the sole component of the base charge (in the case of some surface detonator
20 type initiators), is standard practice in the detonator industry. Accordingly, primary explosives, and in particular lead azide, are widely used by this industry.

This use of primary explosives in the preparation of surface and in-hole detonators, and in particular, the use of lead-containing materials such as lead azide, has several serious disadvantages. These include, for example, (i) that
25 even the presence of a small charge of primary explosive makes a conventional detonator potentially hazardous to handle because of its sensitivity to mechanical deformation or impact; (ii) that the manufacture of the detonator requires the production and handling of significant quantities of sensitive materials which require costly handling procedures; and (iii) that detonator manufacturing plants
30 must address the health risks of dealing with potentially toxic materials such as lead, and address the proper disposal of these toxic materials.

Accordingly, due to the desirability of minimizing or eliminating the use of primary explosives during the production and use of detonators, for, inter alia, safety and/or toxicity reasons, it would be desirable to provide a detonator which was essentially free from primary explosives, and in particular, lead azide.

One approach to the elimination of primary explosives from detonators has been the development of primary explosive-free detonators which rely on the establishment of conditions in the detonator which will cause a secondary explosive to undergo a "deflagration to detonation transition" (DDT) reaction. In these DDT detonators, a deflagration reaction is typically initiated in a secondary explosive by a thermal reaction with an igniting device, such as the flame front from a shock tube, or directly from a heated bridge wire. By suitable confinement of the secondary explosive, and/or control of the secondary explosive particle size, morphology, density, and formulation, as well as careful selection of the initiation means and detonator design, this deflagration reaction is caused to transfer to a detonation reaction which detonation provides sufficient force to initiate an adjacent base charge, or directly initiate a shock tube or length of detonating cord attached to the detonator. Examples of these types of DDT detonators, or other modified detonators, are described in, for example, U.S. Patent No. 2,400,103 (Cobb), U.S. Patent No. 3,096,714 (Yuill), U.S. Patent No. 4,727,808 (Wang et al.), U.S. Patent No. 4,316,412 (Dinegar and Kirkham), PCT Patent Publication No. WO97/22571 (Dumenko) published June 26, 1997, US Patent No. 5385098 (Lindquist et al.), and a related European application numbered as EP-A1-0365503 (Lindquist et al.).

In Dinegar (US 4,316,412) a detonator is described in which a bridgewire is used to initiate a charge of potassium picrate and fine (10 micron) PETN pressed to a high density, in a burning mode. This reaction then progresses to a detonation reaction in an adjacent "transition charge" of fine PETN. The detonation of this transition charge effects detonation of the adjacent base charge. This device, however, is characterised by high confinement both to the sides around the two charges and to the back around the bridgewire. Such high confinement in a standard commercial detonator is not possible due to the limited

dimensions of these detonators and is not desirable due to manufacturing difficulties.

In Wang (US 4,727,808), a fine secondary explosive (PETN < 20 micron and specific surface area of 5000-7000 cm²/g) is used as the initiating charge in order to allow a fast pressure build-up to cause the detonation of the adjacent transition charge of a lower density PETN. This detonation reaction causes the base charge of the detonator to detonate. This design, however, depends on a hot ignition source and strong back confinement provided by a small aperture in the confinement element to allow the fast pressure build-up. This detonator has a high degree of complexity in design, and is relatively expensive to manufacture.

Lindquist (US 5385098) describes a DDT detonator comprising a deflagration section having material in the form of a porous granulated material in order to provide a suitable reaction front. The granulated material is preferably a mixture of a secondary explosive and a combustion catalyst which have been granulated to form granules with a weight average particle size between 10 and 2000 microns; and made up of a plurality of primary crystals having a weight average particle size between 0.1 and 100 microns. The combustion catalyst is a material such as carbon, kryolites or compounds of aluminum, manganese, iron, cobalt, nickel, mercury, silver, zinc, lead, chromium, copper, and mixtures thereof. While providing an improved DDT detonator, this device still requires strong confinement, and in particular, back-confinement of the initiating element which back confinement consists of a cup-shaped confinement shell (with an aperture), which surrounds the initiating element. Use of this cup-shaped confinement shell, together with the preferred use by Lindquist, of back-pressing of the initiating element, adds to the manufacturing cost and complexity of the completed detonator.

Thus, while DDT detonators have shown promise for the replacement of standard primary explosive-containing detonators, their reliability and ease-of-manufacture have led to continued interest in developing additional types of primary explosive-free detonators. In order to overcome these difficulties, other primary explosives-free detonators have been proposed; including devices such

as "flyer" plates (U.S. 3,978,791) or involve the use of lasers (U.S. 3,724,388). However, these have met with little commercial success due to operational and/or manufacturing difficulties.

A further alternative involves the use of high energy pyrotechnics, as
5 described in Canadian patent application No. 2215892.

However, it is still felt in the industry, that it would still be desirable to provide improved performance in a deflagration to detonation transition (DDT) detonator.

Accordingly, in light of the prior art, it would be desirable to provide a
10 composition for use in detonators which is preferably free from primary explosive, and which can be operated without requiring non-standard levels of confinement or the like.

Summary of the Invention

Accordingly, the present invention provides a detonator comprising:

- 15 (i) a hollow detonator shell having an open end and a closed end;
(ii) an igniting device at the open end of said shell;
(iii) optionally one or more delay elements adjacent said igniting device;
(iv) an initiating element comprising an initiation portion and
20 optionally a transition portion; and
(v) optionally a base charge,

characterized in that said initiation portion is at least partially contained within a confinement sleeve and comprises an intimate mixture of a relatively large
particle size, porous, powdered explosive having interstitial spaces, and a
25 relatively small particle size, high-burn-rate, pressurizing initiator located within said interstitial spaces.

For the purposes of this application, the term "porous powdered explosive" refers to an explosive material which when loosely poured into a container, allows

air to pass through the material without a substantial amount of air resistance. The term "powdered" is merely used to indicate that the material is not a liquid or a gas. Preferred materials useful as porous powdered explosives include materials such as pentaerythritoltetranitrate (PETN), cyclotrimethylenetrinitramine (RDX), cyclotetramethylenetetranitramine (HMX), trinitrophenylmethylnitramine (Tetryl), trinitrotoluene (TNT), or combinations thereof. Most preferably, however, the porous powdered explosive is PETN.

When used in the practise of the present invention, the relatively large particle size of the porous powdered explosive creates sufficient interstitial spaces to allow the high-burn-rate, pressurizing initiator to be located within the interstitial spaces even when the mixture is pressed to a desired density within the detonator. Thus, the term "porous" is used to describe a feature of a material to form significant amounts of interstitial spaces contained within the material. A preferred level of porosity is such that the porous, powdered explosive contains, when pressed into place, void spaces of up to 30%, by volume, and more preferably, between 15 and 30% by volume void space.

Further, the shape of the crystals of the porous powdered explosive can also influence the level of interstitial spaces, and thus influence its ultimate reaction properties. For example, a cylindrical configuration would typically allow for the void spaces to have a longer continuous volume when compared to a spherical configuration. Accordingly, cylindrical, prismatic, or generally non-spherical configurations are preferred to spherical or cubic configurations since the void space in the porous powdered explosive would be relatively larger for these configurations. Accordingly, it is preferred that the porous powdered explosive be cylindrical or prismatic in shape and have a crystal aspect ratio of length to width, of at least 3 to 1, and more preferably at least 4 to 1.

As previously stated, the porous powdered explosive is also relatively large when compared with the particle size of the high-burn-rate pressurizing initiator. As a general guideline, it is preferred that the crystal particle size of the porous powdered explosive is greater than 10 times, on average, of the size of the high-burn-rate initiator. Further, it is preferred that the porous powdered explosive

as "flyer" plates (U S. 3,978,791) or involve the use of lasers (U S. 3,724,383). However, these have met with little commercial success due to operational and/or manufacturing difficulties.

A further alternative involves the use of high energy pyrotechnics, as
5 described in Canadian patent application No. 2215892.

However, it is still felt in the industry, that it would still be desirable to provide improved performance in a deflagration to detonation transition (DDT) detonator.

Accordingly, in light of the prior art, it would be desirable to provide a
10 composition for use in detonators which is preferably free from primary explosive, and which can be operated without requiring non-standard levels of confinement or the like.

Summary of the Invention

Accordingly, the present invention provides a detonator comprising:

- 15 (i) a hollow detonator shell having an open end and a closed end;
(ii) an igniting device at the open end of said shell;
(iii) optionally a delay element adjacent said igniting device;
(iv) an initiating element comprising an initiation portion and
20 optionally a transition portion; and
(v) optionally a base charge,

characterized in that said initiation portion is at least partially contained within a confinement sleeve and comprises an intimate mixture of a relatively large particle size, porous, powdered explosive having interstitial spaces, and a
25 relatively small particle size, high-burn-rate pressurizing initiator located within said interstitial spaces.

For the purposes of this application, the term "porous powdered explosive" refers to an explosive material which when loosely poured into a container, allows

air to pass through the material without a substantial amount of air resistance.

The term "powdered" is merely used to indicate that the material is not a liquid or a gas. Preferred materials useful as porous powdered explosives include materials such as pentaerythritoltetranitrate (PETN), cyclotrimethylenetrinitramine (RDX), cyclotetramethylenetetranitramine (HMX), trinitrophenylmethylnitramine (Tetryl), trinitrotoluene (TNT), or combinations thereof. Most preferably, however, the porous powdered explosive comprises PETN.

When used in the practise of the present invention, the relatively large particle size of the porous powdered explosive creates sufficient interstitial spaces to allow the high-burn-rate pressurizing initiator to be located within the interstitial spaces even when the mixture is pressed to a desired density within the detonator. Thus, the term "porous" is used to describe a feature of a material to form significant amounts of interstitial spaces contained within the material. A preferred level of porosity is such that the porous, powdered explosive contains, when pressed into place, void spaces of up to 30%, by volume, and more preferably, between 15 and 30% by volume void space.

Further, the shape of the crystals of the porous powdered explosive can also influence the level of interstitial spaces, and thus influence its ultimate reaction properties. For example, a cylindrical configuration would typically allow for the void spaces to have a longer continuous volume when compared to a spherical configuration. Accordingly, cylindrical, prismatic, or generally non-spherical configurations are preferred to spherical or cubic configurations since the void space in the porous powdered explosive would be relatively larger for these configurations. Accordingly, it is preferred that the porous powdered explosive be cylindrical or prismatic in shape and have a crystal aspect ratio of length to width, of at least 3 to 1, and more preferably at least 4 to 1.

As previously stated, the porous powdered explosive is also relatively large when compared with the particle size of the high-burn-rate pressurising initiator. As a general guideline, it is preferred that the crystal particle size of the porous powdered explosive is greater than 10 times, on average, of the size of the high-burn-rate initiator. Further, it is preferred that the porous powdered explosive

has a number average particle size of between 100 and 500 microns, more preferably between 100 and 300 microns, and most preferably between 100 and 200 microns.

Unless otherwise specified, all particle sizes provided are based on number average particle sizes. Also, unless otherwise noted, all percentages are based on weight percentages.

It should be noted, however, that even with a number average particle size of greater than 100 microns, the porous, powdered explosive may contain particles which range from values below 100 microns. However, the number average size is still greater than 100. Further, the porous, powdered explosive may also contain a small portion of a fine powder having a smaller particle size. This fine powder can have, for example, a particle size of less than 20 microns, or less than 10 microns, or even less than 5 microns. Under some circumstances, however, this small amount of fine powder can assist in the fast ignition and rapid pressurization of the larger porous, powdered explosive particles, and thereby improve the efficiency of the transition from deflagration to detonation. The amount of this fine powder is preferably less than 10%, or more preferably, less than 5%, by weight of the porous, powdered explosive, and is not used to calculate the number average particle size of the porous powdered explosive.

The ultimate porosity of material utilized can be estimated and or adjusted for a given material by controlling the density of the material. For example, a typical sample of PETN has between 15 and 30% void space when tested at a density of 1.2 to 1.5 g/cc.

The term "high-burn-rate pressurising initiator" refers to a fast burning ignition compound or mixture, which has a fast ignition and which also generates an essentially continuous increase in burn rate as gas pressure increases. Preferably, the high-burn-rate initiator has a linear burn rate of greater than 1 cm/sec at a pressure of 2 atmospheres (when measured with a strand burning technique using cylindrical samples of 4 mm diameter or larger, pressed to more than 0.85 g/cc crystal density in a constant pressure bomb as described in Belyaev, A. F. et al. in "Transition from Deflagration to Detonation in Condensed

Phases", Israel Program for Scientific Translations, Jerusalem, 1975 and Svetlov, B. S. and Fogel'zang, A. E., "Combustion of fast burning explosives", Comb., Expl. and Shock Waves, Vol. 5, No. 1, 51, 1969).

More preferably, the burn rate of the high-burn-rate pressurising initiator
5 increases essentially continuously with pressure and reaches a value of greater than 2 cm/sec, and still more preferably, greater than 5 cm/sec, at a pressure of 50 atmospheres.

For example, pure potassium picrate has a linear burn rate of 1.5 cm/sec at 2 atmospheres. This burn rate increase to a maximum of 7 cm/sec at a pressure
10 of 7 to 8 atmospheres. The burn rate then decreases to a value of 2 cm/sec at a pressure of 70 atmospheres. This behaviour makes potassium picrate a candidate for only low pressure applications. However, for higher pressure applications, such as for use as part of an initiation portion of the present invention, this decrease in burn rate is not desirable since it reduces the rate of
15 pressurization of the detonator. When combined with potassium perchlorate, however, the decrease in burn rate is essentially eliminated and the burn rate increases essentially continuously with pressure. Accordingly, the combination of potassium picrate and potassium perchlorate provides a particularly effective mixture for use as the high-burn-rate pressurising initiator in the present
20 invention.

The high-burn-rate pressurising initiator also preferably provides a rapid increase in pressure so as to provide a shock wave suitable for initiation of the porous, powdered explosive. Generally, the high-burn-rate pressurising initiator will provide an increase in gas pressure equal to, or greater than 2 kbar, when
25 measured inside the confinement element which contains at least a part of the initiation portion. In practice, the pressure increase can be estimated from the amount of expansion of the confinement tube. More preferably, the increase in gas pressure will be greater than 5 kbar, and most preferably, will be greater than 10 kbar.

Materials which have a high burn rate, but which do not develop a significant gas pressure increase (in accordance with the values given above) are not preferred in the operation of the present invention.

Preferred materials suitable for use in the high-burn-rate pressurising

- 5 initiator include materials such as potassium picrate, potassium styphnate, lead styphnate, potassium trinitrobenzoate, or alkali or alkaline earth metal salts of nitro-aromatic compounds, and in particular, nitrophenols or nitrobenzoates, or mixtures thereof. More preferably, however, the high-burn-rate pressurising initiator is a mixture of a high burn rate explosive and an oxidizer. A more
- 10 preferred composition for the high-burn-rate pressurising initiator is a mixture of a material having a high-burn-rate at low pressure, such as potassium picrate, potassium styphnate, lead styphnate, or potassium trinitrobenzoate together with an oxidizer such as potassium perchlorate or ammonium perchlorate. A preferred mixture of these materials comprises between 30 and 70% (by weight) oxidizer.
- 15 More preferably, the mixture comprises between 30 and 70% potassium picrate and 30 to 70% potassium perchlorate. More preferably, the mixture comprises between 40 and 60% potassium picrate and potassium perchlorate. Most preferably, the mixture comprises about 50% potassium picrate and about 50% potassium perchlorate.
- 20 With this preferred mixture, high burn rates are possible while also providing good levels of pressurization. This combination provides an improved ability to effect the transition from deflagration to detonation when combined with the PETN. This improved ability can be achieved with decreased levels of confinement and without the need for back-pressing. Thus, this preferred mixture
- 25 provides clear advantages over the DDT formulations of the prior art.

The materials used for the high-burn-rate pressurizing initiator preferably have a particle size small enough in at least one direction so that they can be located within the interstitial spacing in the porous powdered explosive.

- Accordingly, the components of the high-burn-rate pressurizing initiator
- 30 preferably each have a particle size of less than 15 microns, more preferably less

than 10 microns, and even more preferably have a particle size of 5 microns or less.

In the present application, the term "intimate mixture" describes a combination of at least two materials which have been well mixed so that, in the particular mixture of interest in the present invention, the components of the high-burn-rate pressurising initiator is/are located within the interstitial spaces in the porous, powdered explosive(s).

The term "adjacent" when used in this specification means that two materials, such as the base charge and the initiating element, are located sufficiently close to one another that the reaction front passes from one material to the other. Contact between the materials is generally preferred, but is not required.

The initiation portion may contain other materials to modify its performance properties. Preferably, however, the initiation portion comprises at least 10% by weight of said intimate mixture of said porous, powdered explosive and said high-burn-rate pressurising initiator. More preferably, the initiation portion comprises at least 50%, and even more preferably, at least 90%, of said intimate mixture. Most preferably, however, the initiation portion comprises greater than 99% of said intimate mixture.

The ratio of porous powdered material to high-burn-rate pressurising initiator in the intimate mixture of the initiation portion of the initiating element is dependent on the materials selected, and the desired performance properties. However, preferably, the level of porous powdered material is at least 50% (by weight) of said intimate mixture, more preferably greater than 70% of said intimate mixture, and even still more preferably, is greater than or equal to 80% of said intimate mixture. Preferably, the minimum level of high-burn-rate pressurizing initiator is at least 5% of said intimate mixture.

In a most preferred embodiment, both components of the intimate mixture are not primary explosives and thus permit the production of a detonator which is free from primary explosives.

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When present, the transition portion of the initiating element is located between the initiation portion and the base charge (also when present) or the closed end of the detonator. The transition portion is typically a secondary explosive which can be detonated by the reaction front passing through the initiation portion, and which can detonate with sufficient energy to detonate the adjacent base charge material. A preferred material for use as the transition portion is PETN having a particle size of between 75 and 185 microns, and which has a lower density than the base charge. Preferred densities for the initiation portion are between 1.0 and 1.2 g/cc.

10 In a further aspect, the present invention also provides a composition suitable for use in an explosive detonator which comprises an intimate mixture of a porous powdered explosive having interstitial spaces, and a high-burn-rate, pressurizing initiator located within said interstitial spaces.

15 In a still further aspect, the present invention also provides an initiating element comprising an initiation portion and optionally a transition portion characterized in that said initiation portion comprises an intimate mixture of a relatively large particle size, porous, powdered explosive having interstitial spaces, and a relatively small particle size, high-burn-rate, pressurizing initiator located within said interstitial spaces.

20 In a yet still further aspect, the present invention also provides a method of production of the detonators described. Further, the present invention also provides a method of blasting comprising initiating an explosive charge using a detonator, wherein the detonator is as described hereinabove with respect to the present invention.

25 Further objects and advantages of the present invention will be evident from the detailed description of the invention hereinbelow.

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When present, the transition portion of the initiating element is located between the initiation portion and the base charge (also when present) or the closed end of the detonator. The transition portion is typically a secondary explosive which can be detonated by the reaction front passing through the initiation portion and which can detonate with sufficient energy to detonate the adjacent base charge material. The transition portion may comprise PETN, RDX, HMX, Tetryl or a mixture thereof. A preferred material for use as the transition portion is PETN having a particle size of between 75 and 185 microns, and which has a lower density than the base charge. Preferred densities for the initiation portion are between 1.0 and 1.2 g/cc.

In a further aspect, the present invention also provides a composition suitable for use in an explosive detonator which comprises an intimate mixture of a porous powdered explosive having interstitial spaces, and a high-burn-rate, pressurizing initiator located within said interstitial spaces.

In a still further aspect, the present invention also provides an initiating element comprising an initiation portion and optionally a transition portion characterized in that said initiation portion comprises an intimate mixture of a relatively large particle size, porous, powdered explosive having interstitial spaces, and a relatively small particle size, high-burn-rate pressurizing initiator located within said interstitial spaces.

In a yet still further aspect, the present invention also provides a method of production of the detonators described. Further, the present invention also provides a method of blasting comprising initiating an explosive charge using a detonator, wherein the detonator is as described hereinabove with respect to the present invention.

Further objects and advantages of the present invention will be evident from the detailed description of the invention hereinbelow.

Brief Description of the Drawings

The invention may be more clearly understood by reference to the following detailed description of the invention, and the accompanying drawings wherein:

Figures 1 to 3 are cross-sectional drawings of in-hole detonators according to the present invention; and

Figures 4 to 6 are cross-sectional drawings of surface detonators according to the present invention.

Detailed Description of the Preferred Embodiments

The present invention is applicable to both in-hole and surface detonators.

10 Further, the detonators may be electronic, electric or non-electric. The term "detonator" is used in a general sense and is meant to include a variety of initiation devices which may also be referred to as blasting caps, initiators and the like.

The detonator may also be a "delay" detonator, by which term is meant that 15 the detonator comprises means, such as a pyrotechnic delay element, a series of delay elements (e.g. a delay "train"), an electronic timing circuit, or some other device, to cause a time delay between initiation of the igniting device and the subsequent initiation of the initiation portion and/or base charge. However, the detonator may also be an instantaneous, non-delay detonator.

20 It should be noted that the materials used in the production of the delay element (or the delay "train") are typically not gas-generating, or produce very little gas during combustion. This is in distinct contrast to the high-burn-rate pressurising initiator used in the intimate mixture of the present invention.

It should also be noted that the intimate mixture may also include additional 25 materials. However, all percentages values discussed herein are based on the weight ratios of the porous, powdered explosive and the high-burn-rate pressurising initiator, or are based on the total weight of just the initiation portion.

Other additional materials which may be included in the intimate mixture include materials such as explosives, pyrotechnics or propellants. Further, materials such as organic fuels, "inert" organic binders, and the like, which may or may not be consumed during the reaction/detonation may also be present.

- 5 However, preferably the levels of these additional materials is less than 25%, more preferably less than 10% and most preferably, less than 2% of the total weight of the porous, powdered explosive, the high-burn-rate pressurising initiator, and the additional material(s).

- 10 The additional material can include any suitable primary or secondary explosive or initiator which is added to modify the reaction characteristics of the initiation portion, but which does not meet the criteria of being either a porous, powdered explosive or a high-burn-rate pressurising explosive. This can include, for example, materials such as lead azide, or PETN of non-acceptable particle size (e.g. less than 100 microns). However, in light of the stated goal of
- 15 minimizing the use of a primary explosive, it is preferred that the initiation portion be essentially free of added primary explosives.

- A preferred additional material which may be used in combination with the initiation portion is a material which is a "molecular" explosive. Preferred molecular explosives are generally secondary explosive compounds wherein the
- 20 fuel and oxygen are present on the same molecule. Examples of preferred suitable secondary molecular explosives are non-acceptable particle sized PETN, RDX or HMX or mixtures thereof.

- The level of these materials should, however, be low enough so as to not interfere with the intimate mixing of the initiation portion, and thereby interfere
- 25 with the ability to locate the high-burn-rate pressuring initiator within the interstitial spaces of the porous, powdered explosive.

- Examples of other optional additional materials which may be incorporated into the initiation portion include fuels such as finely divided solids including sulphur or carbonaceous materials such as gilsonite, comminuted coke or
- 30 charcoal, carbon black, resin acids, sugars such as glucose or dextrose and other vegetable products such as starch, nut meal, grain meal and wood pulp; and

Other additional materials which may be included in the intimate mixture include materials such as explosives, pyrotechnics or propellants. Further, materials such as organic fuels, "inert" organic binders, and the like, which may or may not be consumed during the reaction/detonation may also be present.

- 5 However, preferably the levels of these additional materials is less than 25%, more preferably less than 10% and most preferably, less than 2% of the total weight of the porous, powdered explosive, the high-burn-rate pressurising initiator, and the additional material(s).

- 10 The additional material can include any suitable primary or secondary explosive or initiator which is added to modify the reaction characteristics of the initiation portion, but which does not meet the criteria of being either a porous, powdered explosive or a high-burn-rate pressurising explosive. This can include, for example, materials such as lead azide, or PETN of non-acceptable particle size (e.g. less than 100 microns). However, in light of the stated goal of
15 minimizing the use of a primary explosive, it is preferred that the initiation portion be essentially free of added primary explosives.

- A preferred additional material which may be used in combination with the initiation portion is a material which is a "molecular" explosive. Preferred molecular explosives are generally secondary explosive compounds wherein the
20 fuel and oxygen are present on the same molecule. Examples of preferred suitable secondary molecular explosives are non-acceptable particle sized PETN, RDX or HMX or mixtures thereof.

- The level of these materials should, however, be low enough so as to not interfere with the intimate mixing of the initiation portion, and thereby interfere
25 with the ability to locate the high-burn-rate pressuring initiator within the interstitial spaces of the porous, powdered explosive.

- Examples of other optional additional materials which may be incorporated into the initiation portion include fuels (typically organic fuels) such as finely divided solids including sulphur or carbonaceous materials such as gilsonite,
30 comminuted coke or charcoal, carbon black, resin acids, sugars such as glucose or dextrose and other vegetable products such as starch, nut meal, grain meal and wood pulp; and

mixtures thereof. Also materials such as propellants and/or gas-generating compounds such as nitrocellulose or sodium azide based propellants, and the like, may be added. Further, binders (preferably energetic binders) such as polymeric materials (including nitrocellulose or GAP (glycidyl azide polymer) can also be included.

Additionally, or alternatively, the formulations of the present invention may be granulated in order to improve their flow properties and in order to reduce dusting. Granulation can be done by forcing a damp mixture through a certain screen size to form granules which are then dried. Granulation can also be done by adding a granulating agent. This agent is usually dissolved in a liquid and mixed with the energetic material(s). The damp mixture is also typically forced through a certain screen size to form granules which are then dried. In this case, the granulating agent acts as a binder to help hold the granules together. When granulated, the granules produced should have a particle size which is at least as large as the particle size of the crystals of the porous, powdered explosive. Accordingly, the present invention also includes detonators, and a production process, wherein all or part of the materials utilized have been subjected to a granulation process.

Granulating agents are well known within the explosives industry. One suitable granulating agent for the formulations described herein is a hydroxypropyl methylcellulose material sold under the trade mark Methocel K4MS (available from Dow Chemical).

The amount of initiation portion present in the initiating element of the detonators of the present invention can vary widely depending on its composition, detonator design, and desired output. These parameters have been previously discussed. For typical situations in a standard sleeve having a 3.8 mm inside diameter (ID), the level of initiation portion is preferably between 10 and 200 mg, more preferably between 50 and 150 mg, and most preferably between 100 and 150 mg.

The amount of transition portion present in the initiating element can also vary widely depending on composition, design and desired output. The transition

portion can also be eliminated under some circumstances. Accordingly, the level of transition portion can, for example, vary from 0 to 200 mg, but more preferably is between 50 and 150 mg. Most preferably the level of transition portion is between 100 and 130 mg.

5 The initiation portion and the transition portion (when present) together form the initiating element. Using the initiating element of the present invention, less confinement of the initiating element is required. Accordingly, the confinement may consist of a simple metal sleeve which is adapted to be fitted within a standard detonator shell. The confinement sleeve is preferably a copper, steel or
10 stainless steel sleeve which is sized so as to closely fit within the shell of a standard detonator. For example, in a standard detonator having an inside diameter (ID) of 6.8 mm, the confinement sleeve will preferably have an outside diameter (OD) of 6.3 mm and a wall thickness of between, for example, 0.1 to 1.5 mm. However, the inner diameter of the confinement sleeve can vary depending
15 on the amount of confinement desired. Most preferably, the confinement sleeve has a wall thickness of about 1.25 mm and is made of steel because of its high strength to mass ratio.

With the formulations of the present invention, it should be noted that the requirement for back-confinement is eliminated, and that there is no need for a
20 cup-shaped confinement means with small apertures. Accordingly, the detonators of the present invention have manufacturing advantages over the prior art DDT detonators.

Under some configurations, it is also possible to eliminate the need for complete confinement of all of the initiating element. Generally, however, it is
25 typically preferable to provide confinement at at least the interface where the initiation portion is first initiated. This aids in ensuring that the DDT reaction has sufficient confinement to transfer from deflagration to detonation within an acceptably short length of the initiation portion and thereby is able to effect detonation of the transition portion or the base charge.

Preferably, all materials used in the production of the intimate mixture of the initiation portion, or more generally, all materials used in the production of the detonators of the present invention, are powdered materials at 20 ° C.

Detonators of the present invention are primarily used in in-hole applications. However, as previously stated, detonators of the present invention may be used in surface applications. These surface detonators typically contain a smaller base charge or omit the base charge. Alternatively, the base charge may be a reduced energy base charge comprising, for example, PETN together with an inert salt.

When present, the base charge may be any of the materials described hereinabove with respect to prior art detonators. However, preferably the base charge used in the detonators of the present invention is a secondary explosive, and more preferably is a molecular secondary explosive. The amount of base charge present will also vary depending on the desired features of the detonator.

However, typical levels for the base charge in an in-hole detonator will range from 100 to 900 mg, and more preferably will be between 200 and 800 mg. Surface detonators will typically contain less of a base charge or a less energetic base charge.

Further, in a surface detonator, the density and length of the initiation portion can be tailored to achieve a low order detonation (i.e. does not achieve full detonation) which does not fragment the confinement sleeve. This design has the advantage that a low order detonation can be used to initiate adjacent shock tubes while reducing the risk of damage resulting from the fragments created caused by a high order detonation. In this embodiment of a surface detonator, the transition charge and/or the base charge can be omitted.

Alternatively, the base charge can be diluted (by an essentially inert substance) or a low density base charge can be used in order to produce a lower pressure detonation which is more suitable for initiation of shock tube. The lower pressure also reduces fragments and therefore, reduces the damages which might be caused by high density, and thus, high pressure base charges.

With the exception of the DDT element, in general, and the composition of the initiating element, in particular, production of the detonators of the present invention is essentially identical to prior art techniques. These techniques for production are well known to those skilled in the art. Using known techniques, all or a portion of the initiating element components may be added to the detonator shell with the confinement sleeve, and pressed to the desired density. Alternatively, all or a portion of the initiating element components may first be pressed into the confinement sleeve prior to inserting the sleeve into the detonator shell.

The addition of a delay element to provide a delay detonator should have little or no impact on the operation of the detonators of the present invention, and manufacture of the delay element is a standard technique in the explosive detonator technology.

The detonator igniting device can be any suitable device which will initiate the delay element and/or directly initiate the initiation portion. Suitable igniting devices include electric "matches", bridge wires, shock tube, safety fuse, detonating cord, or the like, which are inserted into the open end of the detonator shell and which are capable of generating a flame and/or shock wave. Other devices which may be included as igniting devices in the detonators of the present invention include electronic detonator "hotspots", "slapper" detonators, lasers which are capable of generating an energy pulse through, for example, a fibre optic cable, and the like.

As previously discussed, a benefit of using the formulations of the present invention is that the initiating element is able to make the transition from deflagration to detonation in a standard thin wall detonator with limited levels of confinement, and do not require additional heavy confinement means, such as heavy walled steel or copper sleeves and the like. Use of these simpler confinement means is preferable to the confinement means described in the DDT prior art. This improvement provides manufacturing advantages since the design of the detonator may be essentially the same as for prior art detonators. The only significant difference is the replacement of the primary explosive by a simple

cylindrical DDT initiating element which can be manufactured using processes similar to known processes such as, the processes used to produce rigid technology delay elements.

A preferred formulation for the initiation portion of the initiating element, according to the present invention, for use in both surface or in-hole detonators comprises a mixture of 5 to 15% potassium picrate, 5 to 15% potassium perchlorate and 70 to 90% PETN. In this embodiment, the preferred particle size of the materials is as follows: (i) potassium picrate - between 0.5 and 3 microns; (ii) potassium perchlorate - between 1 and 10 microns; and (iii) PETN - between 80 and 120 microns.

It may also be necessary, as is common in this art, to adjust the density of the initiation portion by pressing the mixture during production. Preferably, the density of the initiation portion after pressing is between 1.2 and 1.5 g/cc. However, this may vary depending on the materials selected for production of the initiation portion and may vary depending on the level of confinement selected.

A preferred formulation for the transition portion of the initiating element is the use of PETN having a particle size of between 75 and 180 microns, with a number average particle size of at least 100 microns, and pressing to a density of 1.0 to 1.2 g/cc.

This combined initiating element formulation has demonstrated the ability to produce detonators having properties which are generally equivalent to prior art detonators containing primary explosives. However, a feature of the initiating element of the present invention is that the energy output and VOD, as well as other properties such as sensitivity, heat stability, and the like may be adjusted or modified by changes to the initiating element formulations.

Preferably, the initiating element is formulated to provide acceptable performance standards over a wide temperature range from at least -40 ° C to greater than 120 ° C. Also, it is preferred that the initiating element be formulated so as to be of roughly equivalent length to the initiation portions of prior art detonators. This may be, for example, a length of about 15 to 18 mm but this can vary depending on the detonator design. This permits the detonators produced in

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With exception of the DDT element, in general, and the composition of the initiating element, in particular, production of the detonators of the present invention is essentially identical to prior art techniques. These techniques for production are well known to those skilled in the art. Using known techniques, all or a portion of the initiating element components may be added to the detonator shell with the confinement sleeve, and pressed to the desired density. Alternatively, all or a portion of the initiating element components may first be pressed into the confinement sleeve prior to inserting the sleeve into the detonator shell.

- 10 The addition of a delay element to provide a delay detonator should have little or no impact on the operation of the detonators of the present invention, and manufacture of the delay element is a standard technique in the explosive detonator technology.

- The detonator igniting device can be any suitable device which will initiate the delay element and/or directly initiate the initiation portion. Suitable igniting devices include electric "matches", bridge wires, shock tube, safety fuse, detonating cord, or the like, which are inserted into the open end of the detonator shell and which are capable of generating a flame and/or shock wave. Other devices which may be included as igniting devices in the detonators of the present invention include electronic detonator "hotspots", "slapper" detonators, lasers which are capable of generating an energy pulse through, for example, a fibre optic cable, and the like. Typically, the detonator comprises an electronic detonator.
- 20

- As previously discussed, a benefit of using the formulations of the present invention is that the initiating element is able to make the transition from deflagration to detonation in a standard thin wall detonator with limited levels of confinement, and do not require additional heavy confinement means, such as heavy walled steel or copper sleeves and the like. Use of these simpler
- 25

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confinement means is preferable to the confinement means described in the DDT prior art. This improvement provides manufacturing advantages since the design of the detonator may be essentially the same as for prior art detonators. The only significant difference is the replacement of the primary explosive by a simple
5 cylindrical DDT initiating element which can be manufactured using processes similar to known processes such as, the processes used to produce rigid technology delay elements.

A preferred formulation for the initiation portion of the initiating element, according to the present invention, for use in both surface or in-hole detonators
10 comprises a mixture of a material having a high burn rate at low pressure, such as 5 to 15% potassium picrate, 5 to 15% of an oxidiser, such as potassium perchlorate which together form the pressurising initiator and 70% to 90% PETN. In this embodiment, the preferred particle size of the materials is as follows: (i) potassium picrate – between 0.5 and 3 microns; (ii) potassium perchlorate –
15 between 1 and 10 microns; and (iii) PETN – between 80 and 120 microns.

It may also be necessary, as is common in this art, to adjust the density of the initiation portion by pressing the mixture during production. Preferably, the density of the initiation portion after pressing is between 1.2 and 1.5 g/cc. However, this may vary depending on the materials selected for production of the
20 initiation portion and may vary depending on the level of confinement selected.

A preferred formulation for the transition portion of the initiating element is the use of PETN having a particle size of between 75 and 180 microns, with a number average particle size of at least 100 microns, and pressing to a density of 1.0 to 1.2 g/cc.

25 This combined initiating element formulation has demonstrated the ability to produce detonators having properties which are generally equivalent to prior art detonators containing primary explosives. However, a feature of the initiating element of the present invention is that the energy output and VOD, as well as

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other properties such as sensitivity, heat stability, and the like may be adjusted or modified by changes to the initiating element formulations

Preferably, the initiating element is formulated to provide acceptable performance standards over a wide temperature range from at least -40°C to
5 greater than 120°C. Also, it is preferred that the initiating element be formulated so as to be of roughly equivalent length to the initiation portions of prior art detonators. This may be, for example, a length of about 15 to 18 mm but this can vary depending on the detonator design. This permits the detonators produced in

accordance with the present invention to be of similar length and size to prior art detonators.

One significant feature of the detonators of the present invention is that all materials used for production can be non-primary explosives. Accordingly, the detonators produced may be handled without the precautions necessary for handling primary explosives. Also, because of the low level or absence of primary explosive in the detonators in the preferred embodiments of the present invention, the detonators produced show improved impact resistance and improved propagation resistance over conventional detonators. Impact resistance is a measurement to determine whether a detonator will cause initiation of an outgoing shock tube or detonating cord when the detonator is subjected to the impact of a steel weight dropped from a measured height. For the purposes of this specification, the steel weight is 25 pounds (11.4 kg). Standard detonators of the prior art typically initiate the shock tube or the detonating cord when the steel weight is dropped from a height of 7 feet (2.15 metres) or less for surface detonators, or 4 feet (1.2 metres) or less for in-hole detonators. Accordingly, an impact resistant detonator for the purposes of this specification is one which does not initiate shock tube or detonating cord when the steel weight is dropped from a height of 15 feet (2.3 metres) for a surface detonator and 10 feet (3.1 metres) for an in-hole detonator.

Accordingly, the present invention provides detonators which are impact resistant, according to the definition herein provided, and also provides a process for the production of detonators which are impact resistant.

In a similar manner, the detonators of the present invention have improved resistance to propagation. This property is defined as the ability to resist detonation by a detonator caused by the detonation of an adjacent detonator.

Accordingly, the present invention also provides a surface or in-hole detonator, and a process for producing a detonator, which is propagation resistant. Currently, the formulations and design of the present invention facilitates the development of detonators and low cost packaging which complies with current UN standard 1.4B packaging classification requirements.

With respect to the drawings, it should be noted that a major advantage of the detonators of the present invention is that they can be produced in a fashion similar to existing prior art detonators. Accordingly, the detonators are similar in appearance to prior art detonators with the exception that the traditional, prior art, initiation portions have been replaced by the compositions described in the present invention.

In Figure 1 a non-electric, in-hole delay detonator is shown wherein 1 designates a metal tubular shell with an inside diameter of 6.7 mm, and closed at its bottom end. Within shell 1 is a base charge 2 of 800 mg of PETN (greater than 200 micron particle size) pressed to a density of 1.5 g/cc. Adjacent the base charge 2 is initiating element 3 which consists of a transition portion 4 and an initiation portion 5. Initiation portion 5 is held within confinement sleeve 8 and is an intimate mixture of 10% potassium picrate (2 to 20 micron particle size), 10% potassium perchlorate (3 micron particle size) and 80% PETN (75 to 180 micron particle size) which mixture has been dry mixed and pressed to a density of 1.5 g/cc. Transition portion 4 is also held within confinement sleeve 8 and consists of PETN (75 to 180 micron particle size) which has been pressed to a density of 1.1 g/cc. Sleeve 8 is a cylindrical steel sleeve which has an outside diameter of 6.3 mm and an inside diameter of 3.8 mm.

A delay train of a mixture of red lead, silicon and barium sulphate is shown at 15 and is contained within a metal tube 16. Above delay train 15 is the open end of an inserted shock tube 10 which rests against an anti-static cup 11. Shock tube 10 is held centrally and securely in tube 1 by means of closure plug 12 and crimp 13. When shock tube 10 is initiated at its remote end (not shown) a reaction front passes along the tube, through anti-static cup 11 and ignites delay charge 15. Delay charge 15 burns down to initiation portion 5 at a controlled rate so as to provide the desired delay time. Initiation portion 5 subsequently effects initiation of transition element 4. As the reaction front passes through initiating element 3, a DDT reaction occurs so that initiating element 3 goes through a deflagration to detonation transition. Accordingly, a portion of initiating element 3

eventually detonates. This detonation of initiating element 3 subsequently causes the detonation of base charge 2.

In Figure 2, an electric delay detonator is shown which is similar to the non-electric detonator of Figure 1. In this embodiment, however, the shock tube assembly is replaced with electric match head 26 which is connected to a pair of electrically conducting leads 27. Leads 27 pass through a rubber insert 28 which insert is crimped into place by a crimp 29 in shell 1. Otherwise, all other features are identical to the embodiment described in Figure 1. In Figure 2, and all other subsequent figures, like numerals are used to represent equivalent features.

In operation, an electrical signal passes through leads 27 and causes match head 26 to initiate. The initiation of match head 26 causes delay train 15 to begin burning at its upper end as in the detonator of Figure 1. From this point, operation of this detonator is identical to the detonator of Figure 1.

In Figure 3 a non-electric, instantaneous detonator is shown which is identical to the detonator described in Figure 1 with the exception that delay element 15 and metal tube 16, have been removed so that the reaction front from shock tube 10 directly initiates initiation portion 5. Again, from this point, operation of this detonator is identical to the detonator of Figure 1.

In Figure 4, a non-electric delay surface detonator is shown which is essentially identical to the detonator of Figure 1. However, in this surface detonator, base charge 2 of Figure 1 has been replaced with a lower output base charge 2A consisting of 200 mg of a mixture of 70% by weight PETN and 30% talc.

In Figure 5, an electric surface detonator is shown which is similar to Figure 2. However, base charge 2 has been removed. Detonation of initiating element 3 is utilized to provide initiation of any shock tubes (not shown) which are adjacent to detonator 1.

In Figure 6, a non-electric surface detonator is shown which is similar to the detonator shown in Figure 4 with the exception that base charge 2A and transition portion 4 has been removed. In this embodiment, a larger portion of initiation portion 5 is used alone and undergoes the DDT reaction. The resulting

detonation is utilized to provide initiation of any shock tubes (not shown) which are adjacent to detonator 1.

Numerous variations and modifications of these devices are commonly known within the industry. For example, shock tubes or electric match heads can be replaced by a variety of devices which can effect initiation of the delay train, or instantaneous initiation of the initiation portion in a non-delay detonator. Further, the initiation portion can be directly initiated by a suitable device in an electronic detonator which eliminates the delay train in a delay detonator.

The utility of the invention will now be described, by way of example only, by reference to the following examples.

Examples

A series of detonators (both surface and in-hole types) were prepared using formulations according to the present invention. The detonators were tested for suitability for use. The detonator design and results were as follows:

15 Surface Detonators

Example 1

140 mg of an initiation portion consisting of a mixture of 10 parts of potassium picrate and 90 parts of PETN was poured into a cylindrical steel element 18 mm long, 6.3 mm OD, 3.8 mm id and pressed at 1.5 g/cc density. The remaining space in the element was filled with 100 micron PETN (as a transition portion) and was pressed to a density of 1.1 g/cc. An adhesive paper retaining cover was applied and the element inverted and loaded onto 50 mg of PETN (as a base charge) contained in a 6.7 mm ID detonator shell. A 75 ms delay was placed on top of the steel element and a lead sealer element was crimped on top. The

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detonator was placed in a connector block with 3 shock tubes ahead of the base charge and one to each side. When the detonator was fired using a line of shock tube all the tubes were initiated at both 20° and - 40° C. The shrapnel produced was less than from a conventional surface detonator containing 300 mg of lead azide.

Example 2

The base charge in Example 1 was replaced by 200 mg of a mixture of 70 parts of PETN and 30 parts of talc. The talc was present to dilute the output of the base charge by reducing its detonation velocity and reduce shrapnel production. When fired 5 shock tubes arranged as in Example 1 were initiated and the shrapnel production was less than from a conventional surface detonator.

Example 3

The base charge in Example 1 was removed . When fired up to 6 tubes arranged in a 3 by 2 arrangement ahead of the detonator could be initiated as could 5 tubes arranged as in Example 1 at 20° C. At -40° C, 4 out of 5 tubes were initiated in the latter configuration. The detonator also gave less shrapnel output than a conventional surface detonator.

Example 4

The initiating element from the detonator in Example 3 was filled only with the initiation portion and all other aspects of the detonator remaining the same. When fired it was able to initiate up to 6 shock tubes arranged in a 3 by 2 pattern and produced minimal shrapnel.

Example 5

Steel confinement elements, 18 mm length 6.3 mm OD 3.8 mm ID, were filled with 315 mg of the initiation mixture of Example 1 and pressed to 1.4 to 1.5 g/cc density. The element was loaded into a detonator shell containing a mixture of 10% 60 micron potassium picrate and 90% 75-180 micron PETN confined in an

-24-

inverted brass cup, with a hole in its bottom. The delays were loaded on top of the steel element. The brass cups had an OD of 6.40 mm, an ID of 5.73 mm and the diameter of the hole in its bottom was 2.44 mm. The detonators were tested in the 5 shock tube configuration described in Example 1. The number of shock tubes initiated for the different configurations are shown in the Table 1. The steel elements did not shatter and produced no shrapnel.

$\left(\frac{P}{P_0} \right)_0$
 $\left(\frac{P}{P_0} \right)_1$
 $\left(\frac{P}{P_0} \right)_2$
 $\left(\frac{P}{P_0} \right)_3$
 $\left(\frac{P}{P_0} \right)_4$
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 $\left(\frac{P}{P_0} \right)_7$
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 $\left(\frac{P}{P_0} \right)_{97}$
 $\left(\frac{P}{P_0} \right)_{98}$
 $\left(\frac{P}{P_0} \right)_{99}$
 $\left(\frac{P}{P_0} \right)_{100}$

Table 1: Number of shock tubes (out of 5) initiated for different deflagrative element length and base charge configurations

Base Charge Vol.	Base charge density	Ignition Charge Length mm				
		18	14.5		10	
cc	g/cc	20° C	20° C	-36° C	20° C	-36° C
0.24	1.35	2				
	1.1	4				
	1	5				
	0.9	5, 5	5			
	0.45		5	5	5	5
0.14	0.9		5		0	

In-Hole Detonators

5 Example 6

140 mg of a mixture of 75-180 micron PETN (80% by mass), 2-20 micron potassium picrate (10%) and 3 micron potassium perchlorate (10%) was poured into a 18 mm length 6.3 mm OD, 3.8 mm ID stainless steel tube and pressed to a density of 1.5 g/cc. The remaining space of the tube (the transition portion) was filled with 130 mg of 75 - 180 micron PETN and pressed to a density of 1.1 g/cc. The initiating element form was inserted into a 6.5 mm ID aluminum detonator shell containing 0.8 g PETN base charge pressed to 1.5 g/cc density.

Pyrotechnic delay elements were placed on top of the initiating element followed by a shock tube. Four detonators were tested on aluminum witness blocks and

15 all four detonators produced dents of more than 2 mm depth.

Example 7

Three charge weights of 100, 120 and 140 mg of the same initiation mixture as in Example 6 were pressed to densities of 1.2, 1.3, 1.4 and 1.5 g/cc in stainless steel tubes (6.3 mm OD and 3.8 mm ID) of lengths varying from 15.5 to 18 mm.

- 5 These produced initiation portions of various lengths depending on the mass and density combination. The transition portion was kept at a constant length of 10 mm by filling in the remaining space of the confinement tube with 130 mg of 75 - 180 micron PETN and pressing to a density of 1.1 g/cc. The initiating elements were tested in the same configuration as Example 6 except that the base charge
- 10 was made of an inert material, sodium chloride, pressed to a density of 1.7 g/cc, which closely simulates the dynamic response of PETN at 1.5 g/cc. All initiating elements except one shattered. The only intact piece was from the 100 mg initiation portion with a 1.4 g/cc density which was expanded to 8.9 mm. It is believed that this resulting pressure was more than enough to cause the base
- 15 charge to fully detonate. These tests show that an initiation portion with mass above 100 mg in density range of 1.2 to 1.5 g/cc and the 10 mm column length of transition charge can cause the base charge to detonate.

Example 8

Two electric detonators were made as described in respect of Figure 2. On

- 20 initiation, both detonators produced dents in the aluminum witness block of more than 2 mm.

Example 9

140 mg of an initiation portion consisting of potassium picrate (10%) and PETN (90%), as used in Example 6, was used as the initiation portion in Example 6.

- 25 detonators were made using procedure as Example 6 and when they were fired on aluminum witness blocks. All produced dents of more than 2 mm.

Example 10

244 mg of the initiation portion as in Example 6 was loaded into 18 mm long steel tubes of 6.3 mm OD 5.07 mm ID at a density of 1.4 g/cc and the remaining space was filled with a transition portion of PETN pressed to 1.1 g/cc. Two detonators were made as in Example 6 using these thin walled steel DDT elements. When fired, the two detonators produced dents of more than 2 mm deep in the aluminum witness blocks.

Example 11

225 mg of the initiation portion as in Example 6 was loaded into 18 mm long copper tubes of 6.3 mm OD 5.16 mm ID at a density of 1.35 g/cc and the remaining space was filled with a transition portion of PETN pressed to 1.1 g/cc. Two detonators were made as in Example 6 using these thin walled copper tubes. When the shock tubes were fired, the two detonators produced dents of more than 2 mm deep in the aluminum witness blocks.

Example 12

A test was carried out to evaluate the effect of back venting, which simulates a potential application problems for DDT detonators. These problems are commonly encountered in field application situations and could be caused, for example, by physical distortion of the detonator shell by transmitted shock from adjacent boreholes or misalignment of the delay elements in the manufacture process. Two detonators were prepared as in Example 6 with the addition of a 1.54 mm thick washer (6.4 mm OD and 3.4 mm ID) between the delay element and the initiating element. A venting hole was created in the washer by cutting a 1.25 mm slot radially on the washer and the corresponding location of the aluminum detonator shell was also cut to allow venting. When the shock tubes were fired, both detonators fully detonated producing dents of more than 2 mm on the aluminum blocks.

Example 13

Example 12 was repeated with the initiation mixture of Example 9. Two detonators were made and they did not produce any dents on the aluminum and the OD of the stainless steel tube expanded to only 6.39 mm.

5 Example 14

170 mg of a dry mix of 2-20 micron potassium picrate (10% w/w) and 90-425 micron PETN (90% w/w) was poured into a 28 mm length, 6.3 mm OD, 3.3 mm ID zinc element and pressed at 4.6 kPa. The space in the element was filled with 100 micron (approximate size) recrystallised PETN fraction prepared by
10 controlled crystallization from acetone/water. This charge was pressed at 1.2 kPa. The space left in the element was filled with loose 100 micron PETN and an adhesive paper circle placed over the end of the zinc element. The zinc element was inverted and loaded into a 6.7 mm ID aluminum detonator shell containing a 0.8 g PETN base charge pressed at 5.8 kPa. When initiated by a shock tube, 10
15 out of 10 detonators fired as indicated by witness plates and by damage to the zinc elements.

Example 15

The potassium picrate in Example 14 was replaced by 3-20 micron potassium styphnate. Five out of 5 detonators fired successfully.

20 Example 16

The potassium picrate in Example 14 was replaced by 10-30 micron potassium trinitrobenzoate. Five out of 5 detonators fired successfully.

Example 17

120 mg of a mix of ultra fine PETN (granular shaped particle with average 2
25 micron particle size, surface area ~6800 cm²/g) (80% by mass), 2-20 micron potassium picrate (10%) and 3 micron potassium perchlorate (10%) was poured into a 18 mm length 6.3 mm OD, 3.8 mm ID stainless steel sleeve and pressed to

a density of 1.3 g/cc. The remaining space of the tube (the transition portion) was filled with 150 mg of inert sodium chloride and pressed to a density of 1.3 g/cc. The initiating element was inserted into a 6.5 mm ID aluminum detonator shell containing 0.8 g sodium chloride inert base charge pressed to 1.7 g/cc density.

- 5 Pyrotechnic delay elements were placed on top of the initiating element followed by a shock tube. Three detonators were fired and the average diameter of the expanded steel sleeves was 6.46 mm and the corresponding maximum transient pressure was estimated to be about 3 kbar. The tests were repeated with three other detonators prepared using a larger size PETN (spheroidal shaped with
- 10 average particle size of 160 microns, surface area $\sim 210 \text{ cm}^2/\text{g}$). These three detonators were fired and the average diameter of the expanded steel sleeves was 6.71 mm, the corresponding maximum transient pressure was estimated to be about 6.5 kbar. These experiments demonstrate the utility of the larger PETN particle size in the present invention.

15 **Example 18**

- To illustrate the effect of particle geometry on the effectiveness of the present invention, two types of PETN particles were used. One type had a spherical shape with an aspect ratio of about one and the other had an elongated prismatic shape with an average aspect ratio of about 4. The diameter range of both were
- 20 75 to 180 microns. Example 17 was repeated with two initiation portions using these two types of PETN. 175 mg of these initiation portions were poured into 20 mm length, 6.3 mm OD, 3.8 mm ID stainless steel sleeves and pressed to a density of 1.4 g/cc. The remaining space of the tube (the transition portion) was filled with 150 mg of inert sodium chloride and pressed to a density of 1.3 g/cc.
- 25 These elements were prepared and fired as in Example 12. The average expanded element diameters were found to be 7.55 and 7.1 mm for the particles with aspect ratios of 4 and 1 respectively. The corresponding estimated pressures were 15 and 11 kbar respectively.

Example 19

For comparison, Example 14 was repeated but with a transition portion consisting of PETN (specific surface area of 3300 cm²/g) at a density of 1.6 g/cc as described by Dinegar in US patent No. 4316412. Because of the high density, this charge was pressed first. 170 mg of the potassium picrate-PETN composition of Example 14 was pressed on top and the resulting "initiating element" was loaded into a shell. When initiated by a shock tube, the "initiating element" deflagrated and split the confinement sleeve without fragmenting it. The base charge was not initiated.

Similar results were obtained when PETN with a specific surface area of 3300 cm²/g was used in both the initiation portion and transition portion. These combinations are therefore, not suited to lower confinement conditions as exemplified in the present invention.

Having described specific embodiments of the present invention, it will be understood that modifications thereof may be suggested to those skilled in the art, and it is intended to cover all such modifications as fall within the scope of the appended claims. Additionally, for clarity and unless otherwise stated, the word "comprise" and variations of the word such as "comprising" and "comprises", when used in the description and claims of the present specification, is not intended to exclude other additives, components, integers or steps.

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CLAIMS:

1. A detonator comprising:

- (i) a hollow detonator shell having an open end and a closed end;
- (ii) an igniting device at the open end of said shell;
- (iii) optionally a delay element adjacent said igniting device;
- (iv) an initiating element comprising an initiation portion and optionally a transition portion; and
- (v) optionally a base charge.

characterized in that said initiation portion is at least partially contained within a confinement sleeve and comprises an intimate mixture of a relatively large particle size, porous, powdered explosive having interstitial spaces, and a relatively small particle size, high burn-rate pressurising initiator located within said interstitial spaces.

2. A detonator as claimed in Claim 1 wherein said porous powdered explosive comprises PETN, RDX, HMX, Tetryl, TNT or a mixture thereof.

3. A detonator as claimed in Claim 2 wherein said porous powdered explosive comprises PETN.

4. A detonator as claimed in Claim 3 wherein said PETN has a number average particle size of greater than 100 microns.

5. A detonator as claimed in Claim 1 wherein said high burn-rate pressurising initiator is selected from the group consisting of potassium picrate, potassium styphnate, lead styphnate, potassium trinitrobenzoate, alkali or alkaline earth metal salts of nitro-aromatic compounds, and mixtures thereof.

6. A detonator as claimed in Claim 5 wherein said high burn-rate pressurising initiator is potassium picrate.

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7. A detonator as claimed in Claim 1 wherein said high burn-rate pressurising initiator comprises a mixture of two separate components, namely a material having a high burn rate at low pressure and an oxidizer.

8. A detonator as claimed in Claim 7 wherein said oxidizer comprises
5 potassium perchlorate or ammonium perchlorate.

9. A detonator as claimed in Claim 8 wherein said oxidizer comprises potassium perchlorate.

10. A detonator as claimed in Claim 1 wherein said initiation portion comprises between 5 and 15% by weight of said oxidizer and between 5 and 15%
10 by weight of a material having a high burn rate at low pressure, which together form said pressurising initiator, and 70 to 90% by weight of said porous powdered explosive.

11. A detonator as claimed in Claim 1 wherein said transition portion comprises PETN, RDX, HMX, Tetryl or a mixture thereof.

12. A detonator as claimed in Claim 11 wherein said transition portion
15 comprises PETN.

13. A detonator as claimed in Claim 12 wherein said PETN is pressed to a density of between 1.0 and 1.2 g/cc.

14. A detonator as claimed in Claim 1 wherein said confinement sleeve
20 is a steel, copper or stainless steel sleeve.

15. A detonator as claimed in Claim 14 wherein said confinement sleeve is a circular sleeve having a wall thickness of between 0.1 and 1.5mm.

16. A detonator as claimed in Claim 1 wherein said initiation portion comprises a mixture of 5 to 15% by weight potassium picrate having a number
25 average particle size of less than 10 microns, 5 to 15% by weight potassium perchlorate having a particle size of less than 10 microns, and 70 to 90% by

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weight PETN having a particle size of greater than 100 microns, and wherein said initiation portion has been pressed into a confinement sleeve so as to have a density of between 1.2 and 1.5 g/cc.

17. A detonator as claimed in Claim 16 wherein said transition portion
5 comprises PETN having a particle size of greater than 100 microns and has been pressed into a confinement sleeve so as to have a density of between 1.0 and 1.2 g/cc.

18. A detonator as claimed in Claim 1 wherein said initiation portion
comprises additional components selected from the group consisting of
10 explosives, propellants, gas-generating compounds, organic fuels, binders and combinations thereof.

19. A detonator as claimed in Claim 1 wherein said igniting device
comprises a flame and/or shock wave from an electric match, a bridge wire, a
shock tube, a safety fuse or a detonating cord which is inserted into the open end
15 of the detonator shell.

20. A detonator as claimed in Claim 1 wherein said detonator comprises an electronic detonator.

21. A detonator as claimed in Claim 1 which is essentially free of added primary explosives.

- 20 22. A detonator as claimed in Claim 1 comprising a delay element adjacent said igniting device, so as to form a delay detonator.

23. A detonator as claimed in Claim 1 wherein said detonator is impact resistant.

24. A detonator as claimed in Claim 1 wherein said detonator is
25 propagation resistant.

25. An in-hole detonator comprising:

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- 5 (i) a hollow detonator shell having an open end and a closed end;
(ii) an igniting device at the open end of said shell;
(iii) optionally a delay element adjacent said igniting device;
(iv) an initiating element comprising an initiation portion adjacent said delay element or said igniting device, and optionally a transition portion; and
(v) a base charge,

10 characterized in that said initiation portion is at least partially contained within a confinement sleeve and comprises an intimate mixture of a relatively large particle size, porous, powdered explosive having interstitial spaces, and a relatively small particle size, high burn-rate pressurising initiator located within said interstitial spaces.

26. A surface detonator comprising:

- 15 (i) a hollow detonator shell having an open end and a closed end;
(ii) an igniting device at the open end of said shell;
(iii) optionally a delay element adjacent said igniting device; and
(iv) an initiating element comprising an initiation portion adjacent
20 said delay element or said igniting device, and optionally a transition portion,

characterized in that said initiation portion is at least partially contained within a confinement sleeve and comprises an intimate mixture of a relatively large particle size, porous, powdered explosive having interstitial spaces, and a relatively small
25 particle size, high burn-rate pressurising initiator located within said interstitial spaces.

27. A surface detonator comprising:

- 30 (i) a hollow detonator shell having an open end and a closed end;
(ii) an igniting device at the open end of said shell;

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- (iii) optionally a delay element adjacent said igniting device; and
- (iv) an initiating element comprising an initiating portion adjacent said delay element or said igniting device,

characterized in that said initiation portion is at least partially contained within a
5 confinement sleeve and comprises an intimate mixture of a relatively large particle size, porous, powdered explosive having interstitial spaces, and a relatively small particle size, high burn-rate pressurising initiator located within said interstitial spaces, and wherein said initiation portion achieves only a low order detonation.

28. A surface detonator as claimed in Claim 26 or 27 wherein said
10 detonator additionally comprises a base charge, and wherein the shock wave produced by said base charge is reduced by using a diluted base charge or a low density base charge.

29. An initiating element for use in a detonator comprising an initiation
portion and optionally a transition portion wherein said initiation portion is at least
15 partially contained within a confinement sleeve and comprises an intimate mixture of a relatively large particle size, porous, powdered explosive having interstitial spaces, and a relatively small particle size, high burn-rate pressurising initiator located within said interstitial spaces.

30. A process for manufacturing a detonator as claimed in Claim 1
20 comprising, in order:

- (i) optionally inserting a base charge into a detonator shell;
- (ii) inserting an initiating element comprising an initiation portion and optionally, a transition portion, into said detonator shell;
- (iii) optionally inserting a delay element into said detonator shell;
25 and
- (iv) inserting an igniting device into said detonator shell;

wherein all components are operationally adjacent each other, and wherein said initiation portion comprises an intimate mixture of a relatively large particle size, porous powdered explosive having interstitial spaces, and a relatively small

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particle size, high burn-rate pressurising initiator located within said interstitial spaces.

31. A process as claimed in Claim 30 additionally comprising the step of
5 granulating the initiation portion.

32. A process as claimed in Claim 31 wherein said initiation portion is combined with a granulating agent prior to granulation.

33. A method of blasting comprising initiation of an explosive charge utilising at least one detonator, wherein the at least one detonator is as claimed in
10 Claim 1.

34. A composition suitable for use in an explosive detonator, the composition comprising an intimate mixture of a relatively large particle size, porous, powdered explosive having interstitial spaces, and a relatively small particle size high burn rate pressurising initiator located within said interstitial
15 spaces.

99/830778

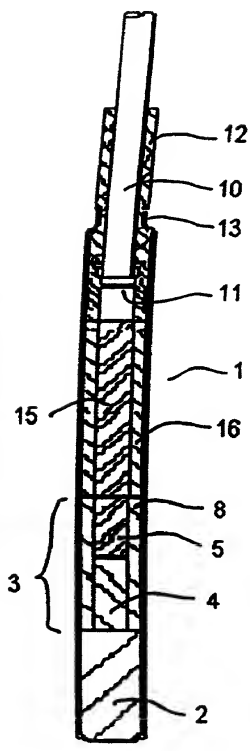


Fig. 1

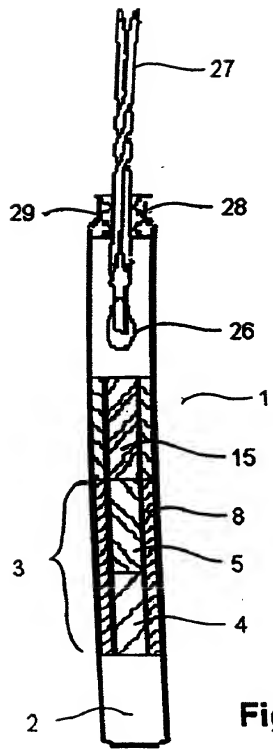


Fig. 2

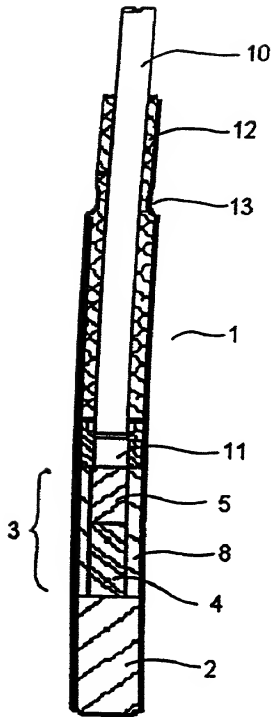


Fig. 3

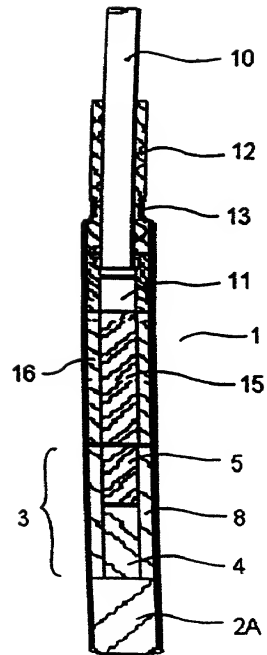


Fig. 4

3/3

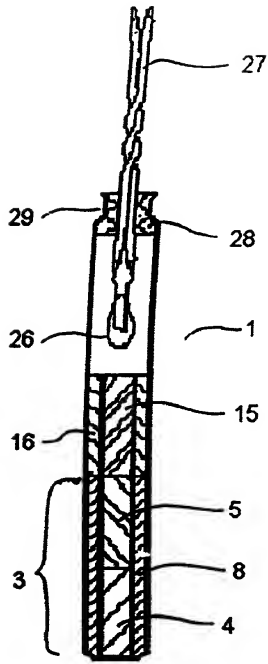


Fig. 5

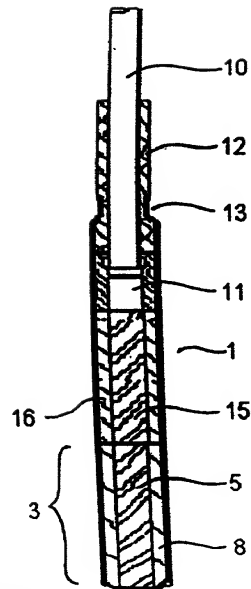


Fig. 6

FOR UTILITY/DESIGN
CIP/PCT NATIONAL/PLANT
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DECLARATIONS

RULE 63 (37 C.F.R. 1.63)
DECLARATION AND POWER OF ATTORNEY
FOR PATENT APPLICATION
IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

PW
FORM

As a below named inventor, I hereby declare that my residence, post office address and citizenship are as stated below next to my name, and I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the INVENTION ENTITLED NON-PRIMARY DETONATORS

the specification of which (CHECK applicable BOX(ES))
X ☐ A. ☐ Is attached hereto.
BOX(ES) ☒ B. ☒ Was filed on May 1, 2001 as U.S. Application No. /
☒ C. ☒ Was filed as PCT International Application No. PCT/ AU99/00940 on October 29, 1999
and (if applicable to U.S. or PCT application) was amended on May 26, 2000

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above. I acknowledge the duty to disclose all information known to me to be material to patentability as defined in 37 C.F.R. 1.56. Except as noted below, I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT International Application which designated at least one other country than the United States, listed below and have also identified below any foreign application for patent or inventor's certificate, or PCT International Application, filed by me or my assignee disclosing the subject matter claimed in this application and having a filing date (1) before that of the application on which priority is claimed, or (2) if no priority claimed, before the filing date of this application:

PRIOR FOREIGN APPLICATION(S)

Number	Country	Day/MONTH/Year Filed
2,252,353	CANADA	4 November 1998
PQ 2315	AUSTRALIA	19 August 1999

**Date first Laid-
open or Published**

**Date Patented
or Granted**

Priority NOT Claimed

If more prior foreign applications, X box at bottom and continue on attached page.

Except as noted below, I hereby claim domestic priority benefit under 35 U.S.C. 119(e) or 120 and/or 365(c) of the indicated United States applications listed below and PCT international applications listed above or below and, if this is a continuation-in-part (CIP) application, insofar as the subject matter disclosed and claimed in this application is in addition to that disclosed in such prior applications, I acknowledge the duty to disclose all information known to me to be material to patentability as defined in 37 C.F.R. 1.56 which became available between the filing date of each such prior application and the national or PCT international filing date of this application:

PRIOR U.S. PROVISIONAL, NONPROVISIONAL AND/OR PCT APPLICATION(S)

Application No. (series code/serial no.) **Day/MONTH/Year Filed**

Status
pending, abandoned, patented

Priority NOT Claimed

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

And I hereby appoint Pillsbury Winthrop LLP, Intellectual Property Group, telephone number (202) 881-3000 (to whom all communications are to be directed), and persons of that firm who are associated with USPTO Customer No. 909 (see below label) individually and collectively my attorneys to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith and with the resulting patent, and I hereby authorize them to delete from that Customer No. names of persons no longer with their firm, to add new persons of their firm to that Customer No., and to act and rely on instructions from and communicate directly with the person/assignee/attorney/firm/organization who/which first sends/sent this case to them and by whom/which I hereby declare that I have consented after full disclosure to be represented unless/until I instruct the above firm and/or an attorney of that firm in writing to the contrary.

USE ONLY FOR
PILLSBURY WINTHROP



00909

(1) INVENTOR'S SIGNATURE:

Date: 5/7/2001

Name	John	COOPER	
First	John	Middle Initial	
Residence	Scotland	GREAT BRITAIN	GREAT BRITAIN
City		State/Foreign Country	Country of Citizenship
Mailing Address	11 Lamford Drive, Ayr, Scotland, United Kingdom		
(include Zip Code)	KA7 4DE		

(2) INVENTOR'S SIGNATURE:

Date:

Name	David	Proven	SUTTON
First	David	Middle Initial	
Residence	North Yorkshire	GREAT BRITAIN	GREAT BRITAIN
City		State/Foreign Country	Country of Citizenship
Mailing Address	8 Peacocks Close, Stokesley, North Yorkshire, United Kingdom		
(include Zip Code)	TS9 5QD		

☒ FOR ADDITIONAL INVENTORS see attached page.

☐ See additional foreign priorities on attached page (incorporated herein by reference).

Atty. Dkt. No. P 280281

(M#)

FOR UTILITY/DESIGN
CIP/PCT NATIONAL/PLANT
ORIGINAL/SUBSTITUTE/SUPPLEMENTAL
DECLARATIONS

RULE 63 (37 C.F.R. 1.63)
DECLARATION AND POWER OF ATTORNEY
FOR PATENT APPLICATION

PW
FORM

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

As a below named inventor, I hereby declare that my residence, post office address and citizenship are as stated below next to my name, and I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the **INVENTION ENTITLED NON-PRIMARY DETONATORS**

the specification of which (CHECK applicable BOX(ES))

X
BOX(ES) → A. ☐ is attached hereto.
→ B. ☒ was filed on May 1, 2001 as U.S. Application No. /
→ C. ☒ was filed as PCT International Application No. PCT/ AU99/00940 on October 29, 1999
and (if applicable to U.S. or PCT application) was amended on May 26, 2000

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above. I acknowledge the duty to disclose all information known to me to be material to patentability as defined in 37 C.F.R. 1.56. Except as noted below, I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT International Application which designated at least one other country than the United States, listed below and have also identified below any foreign application for patent or inventor's certificate, or PCT International Application, filed by me or my assignee disclosing the subject matter claimed in this application and having a filing date (1) before that of the application on which priority is claimed, or (2) if no priority claimed, before the filing date of this application:

PRIOR FOREIGN APPLICATION(S)

Number	Country	Day/MONTH/Year Filed
2,252,353	CANADA	4 November 1998
PQ 2315	AUSTRALIA	19 August 1999

**Date first Laid-
open or Published**

**Date Patented
or Granted**

Priority NOT Claimed

If more prior foreign applications, X box at bottom and continue on attached page.

Except as noted below, I hereby claim domestic priority benefit under 35 U.S.C. 119(e) or 120 and/or 365(c) of the indicated United States applications listed below and PCT international applications listed above or below and, if this is a continuation-in-part (CIP) application, insofar as the subject matter disclosed and claimed in this application is in addition to that disclosed in such prior applications, I acknowledge the duty to disclose all information known to me to be material to patentability as defined in 37 C.F.R. 1.56 which became available between the filing date of each such prior application and the national or PCT international filing date of this application:

PRIOR U.S. PROVISIONAL, NONPROVISIONAL AND/OR PCT APPLICATION(S)

Application No. (series code/serial no.) **Day/MONTH/Year Filed**

Status

Priority NOT Claimed

pending, abandoned, patented

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

I And I hereby appoint Pillsbury Winthrop LLP, Intellectual Property Group, telephone number (202) 861-3000 (to whom all communications are to be directed), and persons of that firm who are associated with USPTO Customer No. 909 (see below label) individually and collectively my attorneys to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith and with the resulting patent, and I hereby authorize them to delete from that Customer No. names of persons no longer with their firm, to add new persons of their firm to that Customer No., and to act and rely on instructions from and communicate directly with the person/assignee/attorney/firm/ organization who/which first sends/sent this case to them and by whom/which I hereby declare that I have consented after full disclosure to be represented unless/until I instruct the above firm and/or an attorney of that firm in writing to the contrary.

USE ONLY FOR
PILLSBURY WINTHROP



00909

(1) INVENTOR'S SIGNATURE:

Date:

Name	John	COOPER	
	First	Middle Initial	Family Name
Residence	Scotland	GREAT BRITAIN	GREAT BRITAIN
	City	State/Foreign Country	Country of Citizenship
Mailing Address	11 Lamford Drive, Ayr, Scotland, United Kingdom		
(include Zip Code)	KA7 4DE		

(2) INVENTOR'S SIGNATURE:

Date:

Name	David	Proven	SUTTON
	First	Middle Initial	Family Name
Residence	North Yorkshire	GREAT BRITAIN	GREAT BRITAIN
	City	State/Foreign Country	Country of Citizenship
Mailing Address	8 Peacocks Close, Stokesley, North Yorkshire, United Kingdom		
(include Zip Code)	TS9 5QD		

☒ FOR ADDITIONAL INVENTORS see attached page.

☐ See additional foreign priorities on attached page (incorporated herein by reference).

Atty. Dkt. No. P 280281

(M#)

DECLARATION AND POWER OF ATTORNEY

(continued)

ADDITIONAL INVENTORS:

(3) INVENTOR'S SIGNATURE:

Date: 3-July-2001

Sek	Kwan	CHAN
First	Middle Initial	Family Name
Residence	Quebec	CANADA
City	State/Foreign Country	Country of Citizenship
Mailing Address	4076 Kuchiran Street, Pierrefonds, Quebec, Canada	
(include Zip Code)	H9H 4A9	

(4) INVENTOR'S SIGNATURE:

Date:

First	Middle Initial	Family Name
Residence	City	State/Foreign Country
Mailing Address	Country of Citizenship	
(include Zip Code)		

(5) INVENTOR'S SIGNATURE:

Date:

First	Middle Initial	Family Name
Residence	City	State/Foreign Country
Mailing Address	Country of Citizenship	
(include Zip Code)		

(6) INVENTOR'S SIGNATURE:

Date:

First	Middle Initial	Family Name
Residence	City	State/Foreign Country
Mailing Address	Country of Citizenship	
(include Zip Code)		

(7) INVENTOR'S SIGNATURE:

Date:

First	Middle Initial	Family Name
Residence	City	State/Foreign Country
Mailing Address	Country of Citizenship	
(include Zip Code)		

(8) INVENTOR'S SIGNATURE:

Date:

First	Middle Initial	Family Name
Residence	City	State/Foreign Country
Mailing Address	Country of Citizenship	
(include Zip Code)		

(9) INVENTOR'S SIGNATURE:

Date:

First	Middle Initial	Family Name
Residence	City	State/Foreign Country
Mailing Address	Country of Citizenship	
(include Zip Code)		

Rule.56(a) & (b) = 37 C.F.R. 1.56(a) & (b)
PATENT AND TRADEMARK CASES - RULES OF PRACTICE
DUTY OF DISCLOSURE

- (a) ... Each individual associated with the filing and prosecution of a patent application has a duty of candor and good faith in dealing with the [Patent and Trademark] Office, which includes a duty to disclose to the Office all information known to that individual to be material to patentability... (b) information is material to patentability when it is not cumulative and (1) It also establishes by itself, or in combination with other information, a prima facie case of unpatentability of a claim or (2) refutes, or is inconsistent with, a position the applicant takes in: (i) Opposing an argument of unpatentability relied on by the Office, or (ii) Asserting an argument of patentability

PATENT LAWS 35 U.S.C.

§102. Conditions for patentability; novelty and loss of right to patent

A person shall be entitled to a patent unless--

- (a) the invention was known or used by others in this country, or patented or described in a printed publication in this or a foreign country, before the invention thereof by the applicant for patent or
- (b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of the application for patent in the United States, or
- (c) he has abandoned the invention, or
- (d) the invention was first patented or caused to be patented, or was the subject of an inventor's certificate, by the applicant or his legal representatives or assigns in a foreign country prior to the date of the application for patent in this country on an application for patent or inventor's certificate filed more than twelve months* before the filing of the application in the United States, or
- (e) the invention was described in a patent granted on an application for patent by another filed in the United States before the invention thereof by the applicant for patent, or on an international application by another who has fulfilled the requirements of paragraphs (1), (2), and (4) of section 371(c) of this title before the invention thereof by the applicant for patent, or
- (f) he did not himself invent the subject matter sought to be patented, or
- (g) before the applicant's invention thereof the invention was made in this country by another who had not abandoned, suppressed, or concealed it. In determining priority of invention there shall be considered not only the respective dates of conception and reduction to practice of the invention, but also the reasonable diligence of one who was first to conceive and last to reduce to practice, from a time prior to conception by the other.

§103. Condition for patentability; non-obvious subject matter

- (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negated by the manner in which the invention was made. . . .
- (c) Subject matter developed by another person, which qualified as prior art only under subsection (f) or (g) of section 102 of this title, shall not preclude patentability under this section where the subject matter and the claimed invention were, at the time the invention was made, owned by the same person or subject to an obligation of assignment to the same person.

* Six months for Design Applications (35 U.S.C. 172).